Comparative Analysis of OMI/OMAERUV and AERONET Retrieval of Single-scattering Albedo in Biomass Burning and Dust Environments

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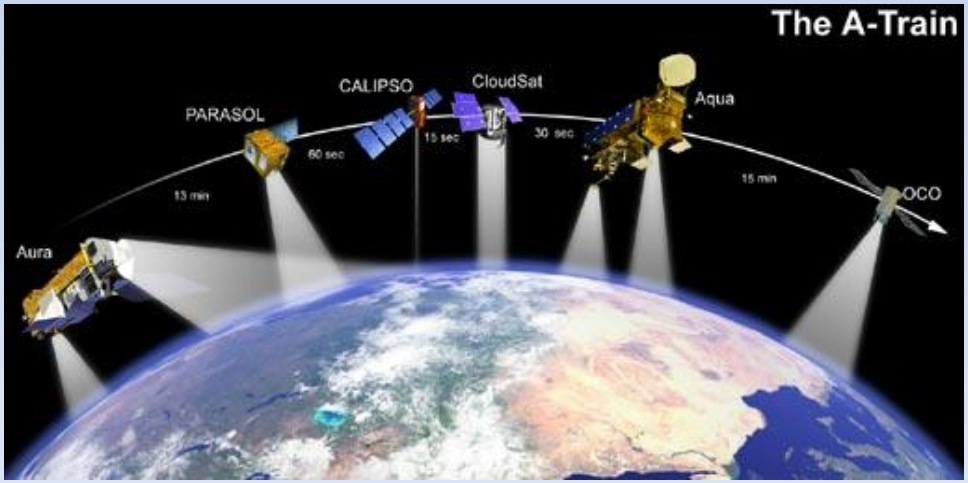
What is OMI?

- A hyper-spectral instrument on board **NASA's AURA** satellite
- **Launch date:** July 15, 2004
- A successor of successful **TOMS instrument**
- **Spectral range:** 270-500 nm
- **Purpose:** To derive Ozone, NO_2, SO_2, BrO, OClO, and **aerosols**
- TOMS+OMI provide longest record on ozone and aerosols



OMI foot print size 13X24 km²

http://aura.gsfc.nasa.gov/instruments/omi.html

UV-Aerosol Index

Step 1: Estimation of lambertian equivalent reflectivity at 388

$$I_{388} = I_{0388} + \frac{R_{388}T}{1 - S_b R_{388}}$$

Step 2: Estimation of radiance at 354 assuming LER@388 nm

$$I_{354}^{calc} = I_{0354} + \frac{R_{388}T}{1 - S_b R_{388}}$$

Step 3: Computation of UV-AI

$$UVAI = -100 * \log\left(\frac{I_{354}^{meas}}{I_{354}^{calc}}\right)$$

- Qualitative indicator of elevated absorbing aerosols such as dust and smoke
- Positive AI for absorbing aerosols
- Negative AI for scattering aerosols
- Near-zero AI for clouds
- Used in numerous studies and publications for detection of UV-absorbing aerosols

Near-UV Aerosol Retrieval

Torres et al., (2007), JGR

Spectral measurements of reflected radiance at TOA
354 nm, 388 nm

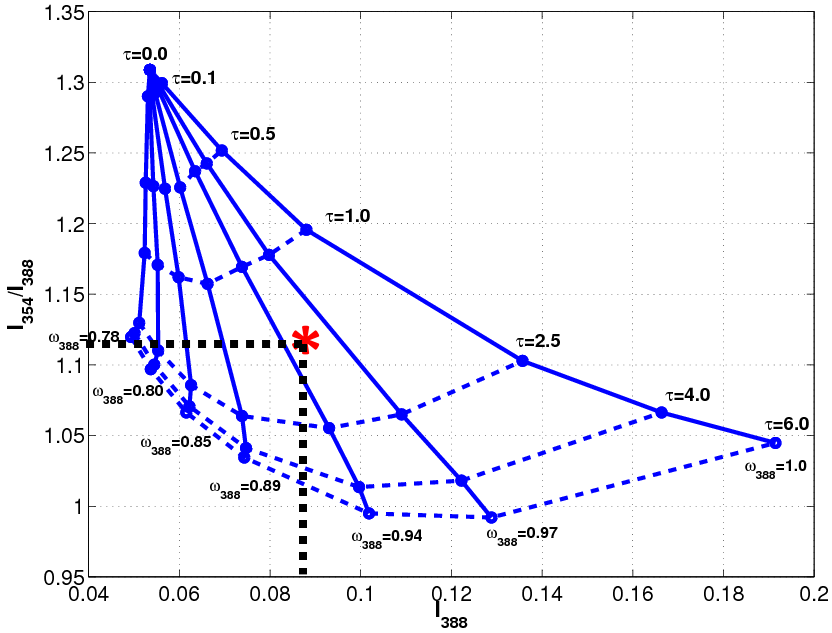
↓

Look-up-table
Aerosol types: Smoke, dust, and industrial
Each aerosol type has 7 aerosol models

Layer heights=0.0, 1.5, 3.0, 6.0, 10.0
SZA=0, 20, 40, 60, 66, 72, 80
VZA= 0, 12, 18, 26, 32, 36, 40, 46, 50, 54, 56, 60, 66, 72
PHI=0 to 150 in step of 30 and then 160 to 180 in step of 5

↓

Aerosol type selection
Surface albedo
Aerosol layer height



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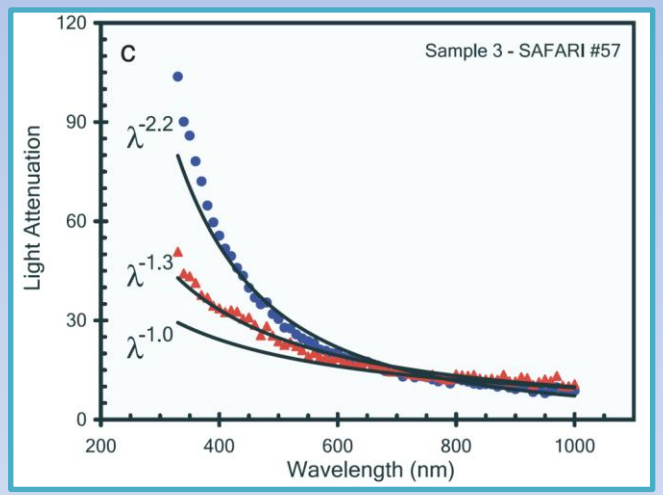
Retrieved Aerosol Parameters
aerosol optical depth,
single-scattering albedo at 388 nm

Converted AOD and SSA at 354 and 500 nm

Recent Changes in the OMAERUV algorithm

1. Updated Carbonaceous aerosol models

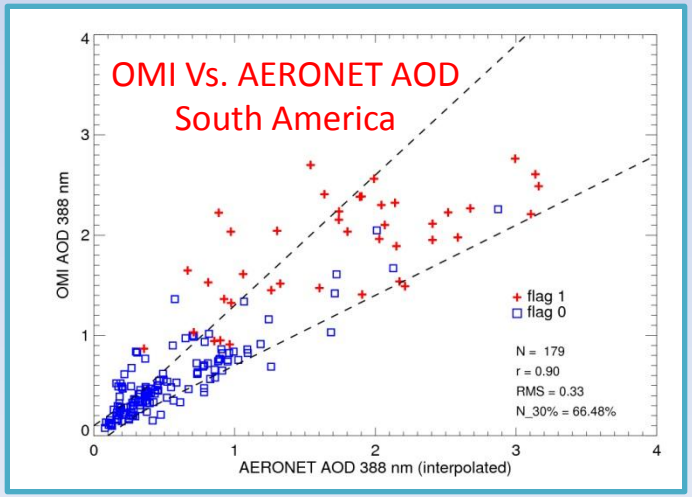
Kirchstetter et al. (2004)



Jethva & Torres, ACP (2011)

No Spectral Dependence		20 % Spectral Dependence		30 % Spectral Dependence	
Img. Ref. Index 388/354	α_{abs}	Img. Ref. Index 388/354	α_{abs}	Img. Ref. Index 388/354	α_{abs}
0.048/0.048	1.01	0.048/0.0576	2.49	0.048/0.0624	3.12
0.040/0.040	1.03	0.040/0.0480	2.54	0.040/0.0520	3.20
0.030/0.030	1.06	0.030/0.036	2.62	0.030/0.0390	3.29
0.020/0.020	1.07	0.020/0.024	2.67	0.020/0.0260	3.37
0.010/0.010	1.11	0.010/0.012	2.84	0.010/0.0130	3.60
0.005/0.005	1.13	0.005/0.006	2.92	0.005/0.0650	3.70
0.000/0.000	N/A	N/A	N/A	N/A	N/A

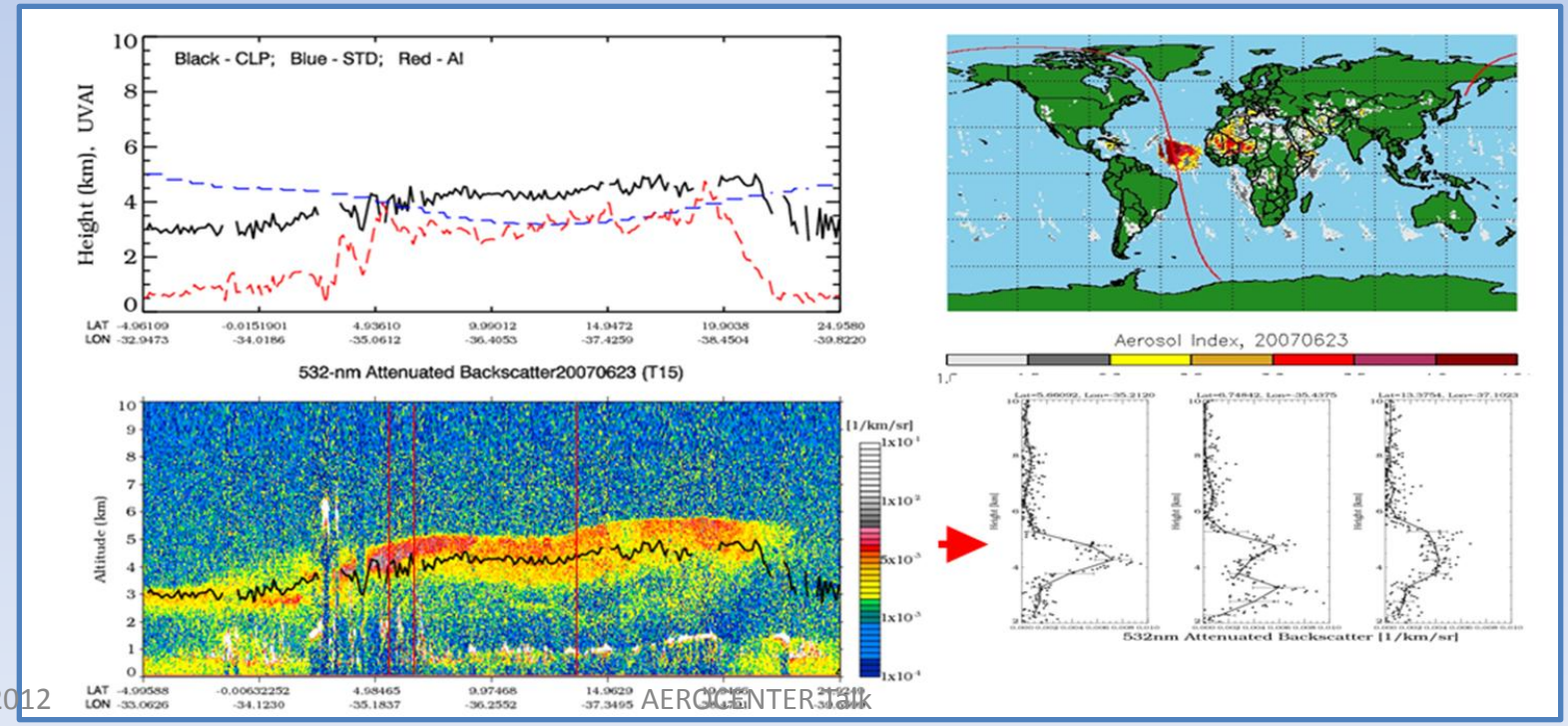
Wavelength-dependent imaginary index in the near-UV region is a strong proxy for the presence of organics



Recent Changes in the OMAERUV algorithm

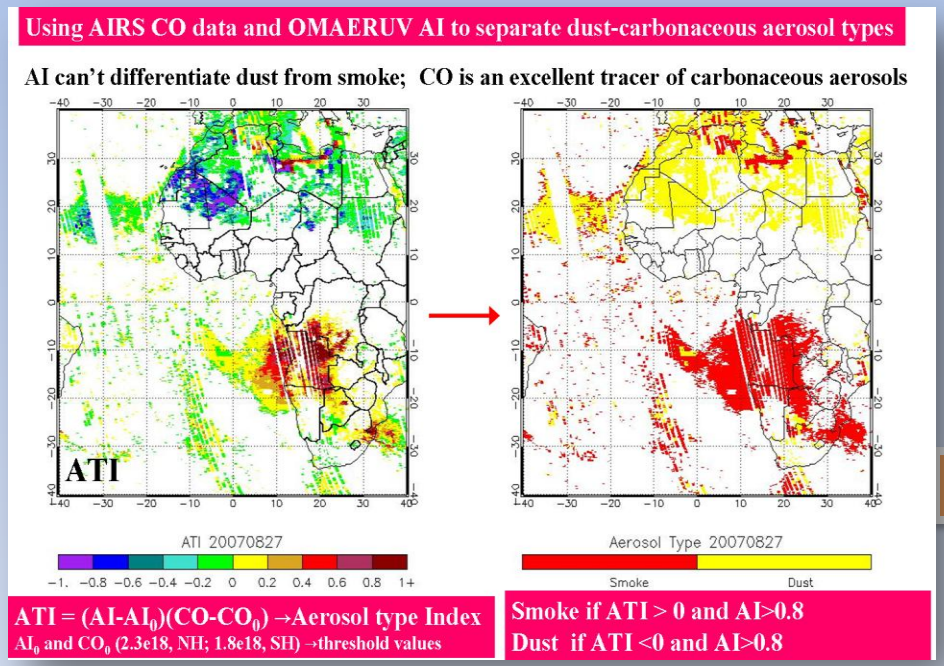
2. Determination of aerosol layer height using CALIOP measurements

- ❑ Use of CALIOP 532 nm aerosol back-scatter profile of extinction in conjunction with OMI UV-AI
- ❑ Cloud-free CALIOP and OMI (UV-AI>1.5) pixels are collocated in time and space
- ❑ Averaging of extinction coef. at each and all levels of collocated CALIOP profiles
- ❑ Derivation of mean aerosol height as extinction coef. weighted averaged profile
- ❑ Record of CALIOP and OMI data used in making of monthly climatology: July 1, 2006 to June 30, 2008 (30 months)



Recent Changes in the OMAERUV algorithm

3. Use of AIRS Carbon Monoxide (CO) and UV-AI for the aerosol type identification



SMOKE

(AI >= 0.8 & CO > 1.8 for the S.H) OR
(AI >= 0.8 & CO > 2.2 for the N.H) OR
(CO > 2.5 for the S.H) OR
(CO > 2.8 for the N.H)

DUST

AI >= 0.8 OR (Arid and Semi-Arid surface types)

SULPHATE (if above conditions not satisfied)

Publications on this work…

1. *Satellite-based evidence of wavelength aerosol absorption in biomass burning smoke inferred from Ozone Monitoring Instrument, ACP, Jethva and Torres, 2011*

http://www.atmos-chem-phys.net/11/10541/2011/acp-11-10541-2011.html

2. Comparative study of aerosol and cloud detected by CALIPSO and OMI Zhen, Torres, McCormick, Smith and Ahn, Atmospheric Environment, 2012

http://www.sciencedirect.com/science/article/pii/S1352231012000453

In preparation

3. *Comparative Analysis of OMI/OMAERUV and AERONET Retrieval of Single scattering Albedo in the Biomass Burning and Dust Environments by Jethva et al.*

4. *Evaluation of AOD from the OMI UV Aerosol Algorithm by Ahn et al.*

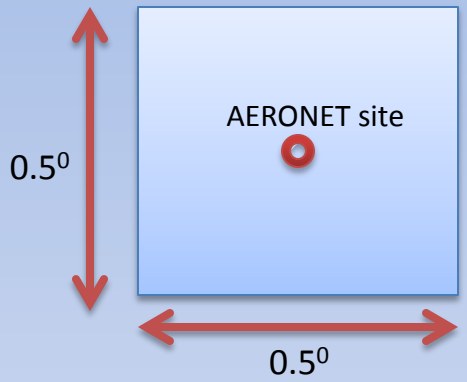
5. *Global distribution of aerosol absorption optical depth and single scattering albedo from OMI observations by Torres, Ahn, Jethva*

Re-processing of OMI Record

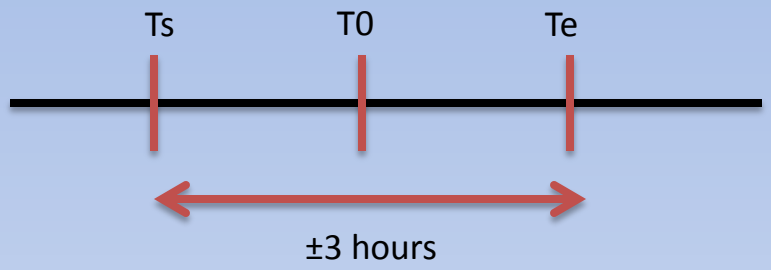
- Entire OMI record **(2004-to-preset)** was reprocessed with the updated algorithm.
- Re-processed retrievals were compared with the AERONET.
- **This talk:** SSA comparison.
- For AOD comparison, please refer to Changwoo's AGU 2011 poster content.

Co-location Methodology

OMI retrieval spatial averaging



AERONET retrieval temporal averaging



Level 2.0 dataset
Minimum required AERONET measurements = 1

OMI Version 1.3.7, Collection 3, Level 2)
Minimum required OMI Pixels = 1

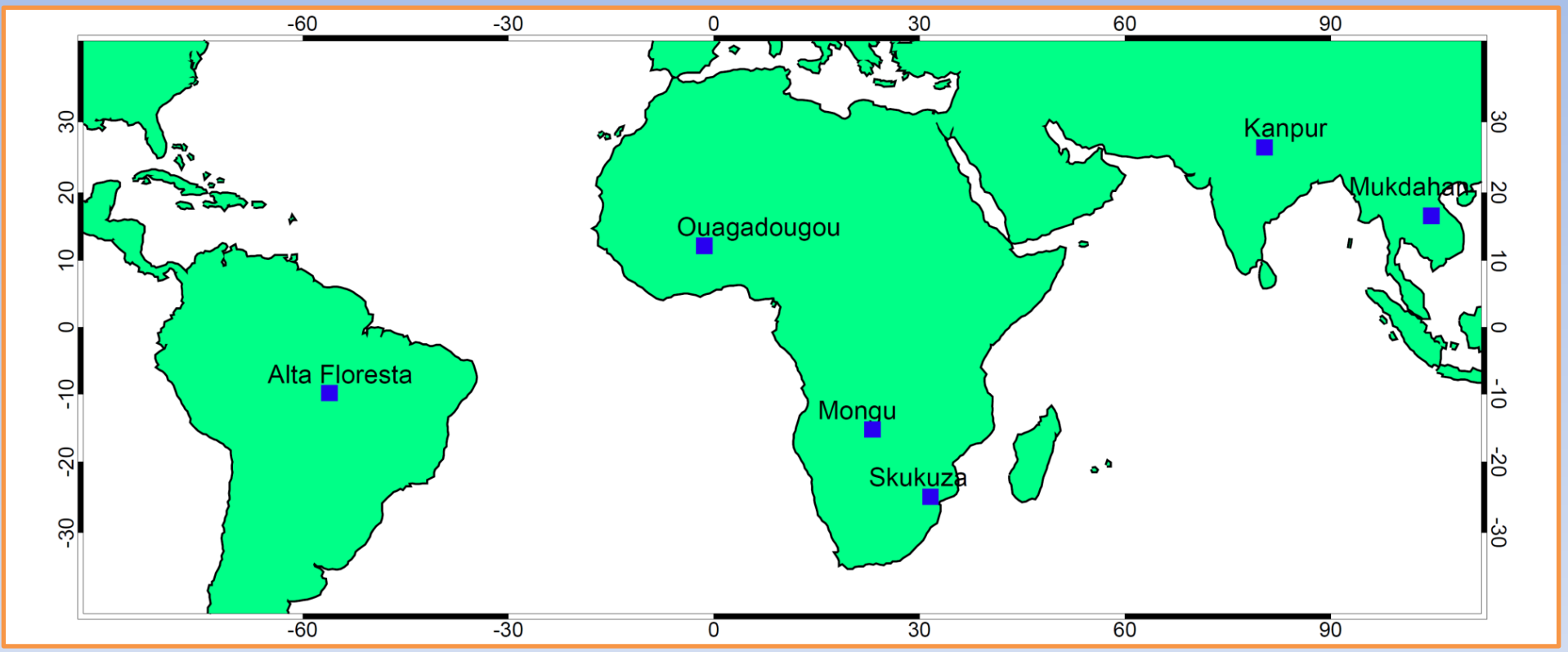
Wavelength conversion:
OMI and AERONET derive aerosol absorption at different wavelengths

OMI retrieval at 388 nm, converted to 354 and 388 nm

AERONET retrievals at 440 , 670, 870, 1020 nm

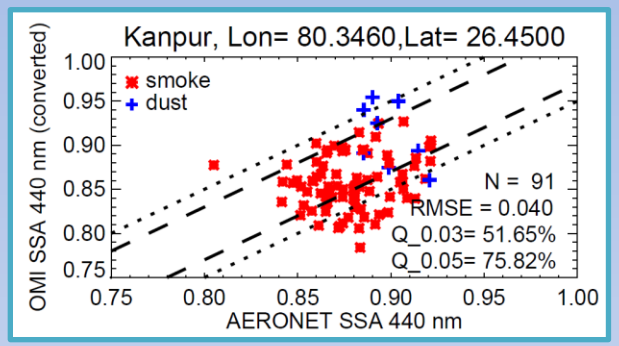
OMI SSA interpolated to 440 nm ⟷ AERONET retrievals at 440 nm

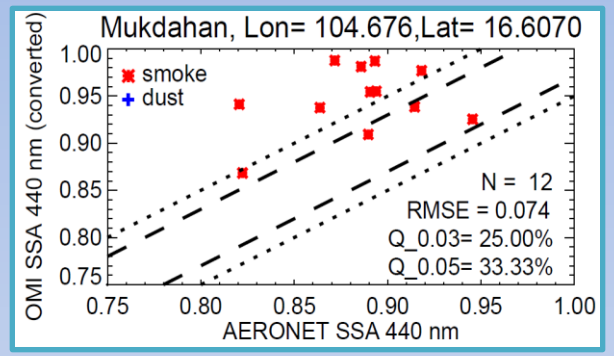
Biomass Burning Sites

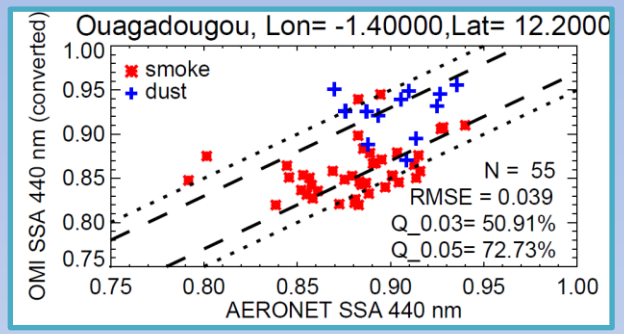


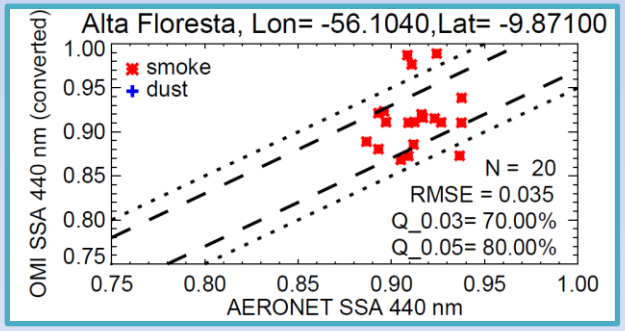
OMI Vs. AERONET

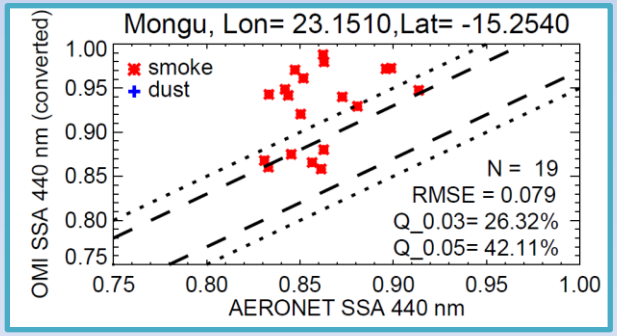
Biomass Burning Sites

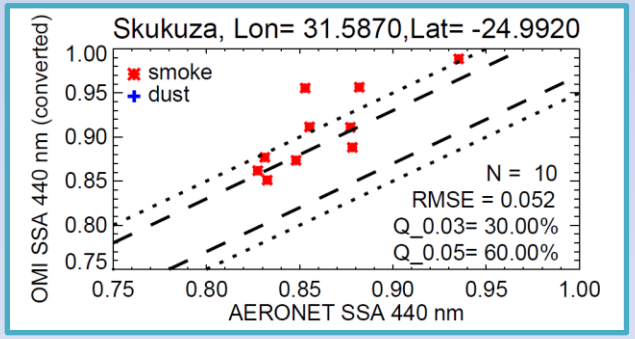




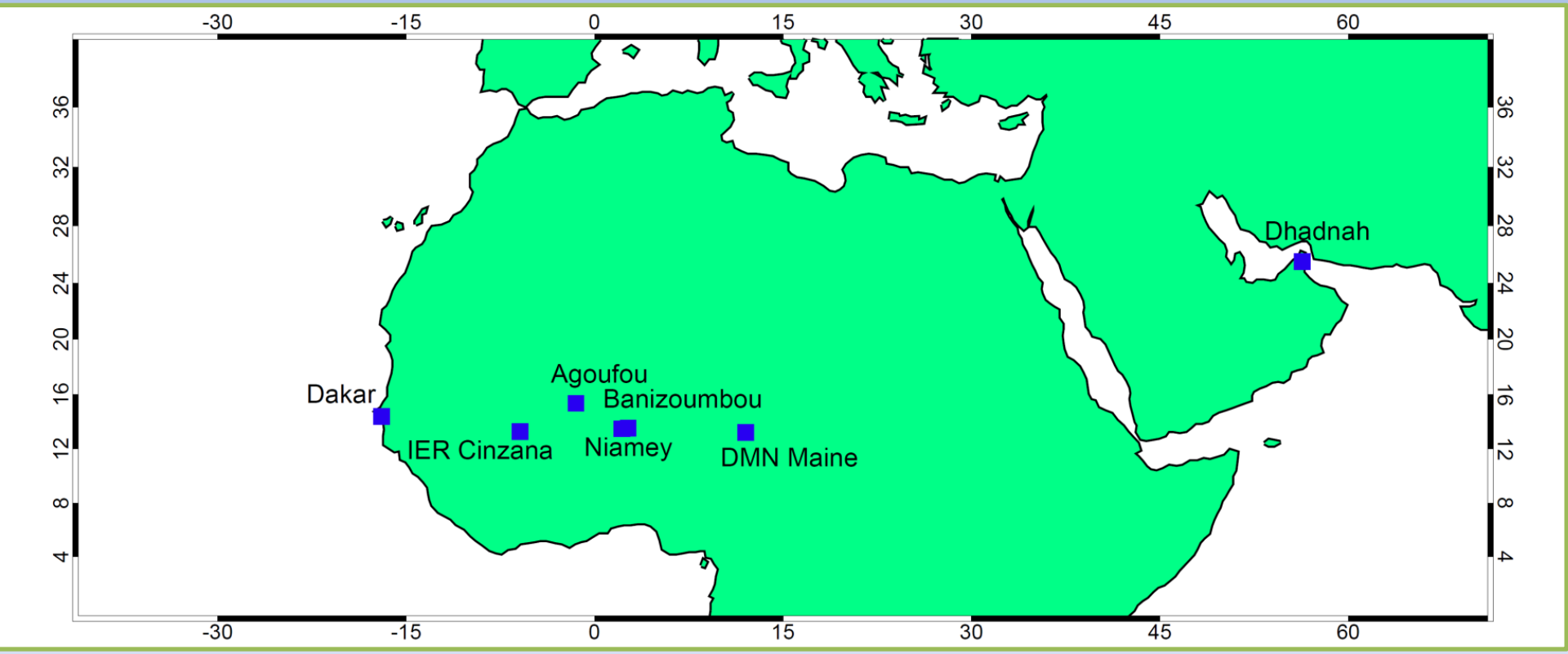




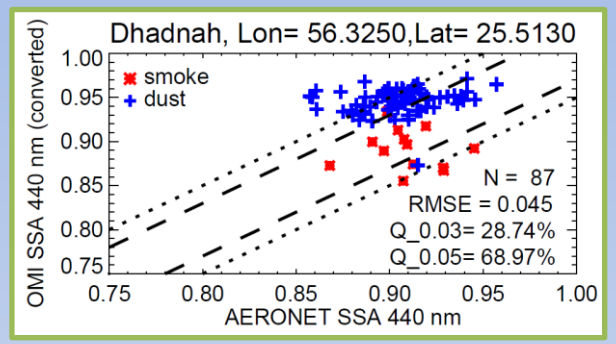


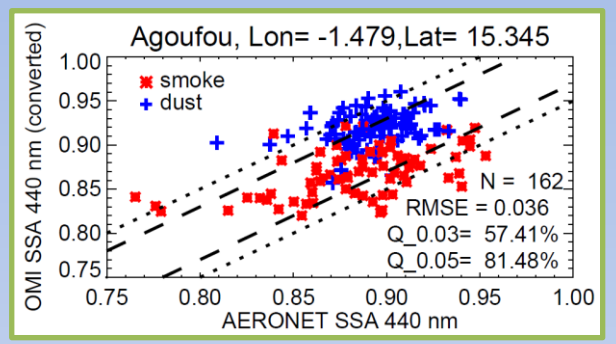


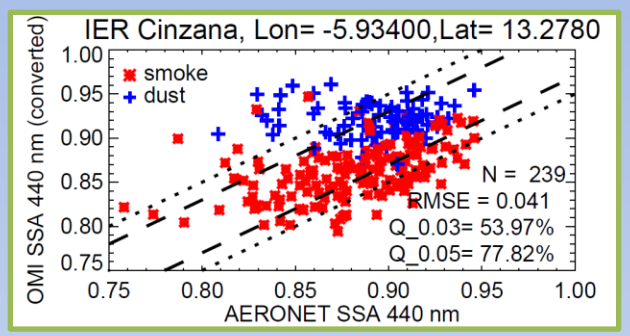
Seasonal Biomass Burning and Dust Sites

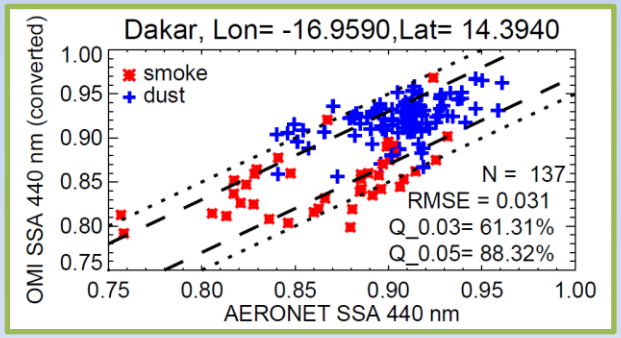


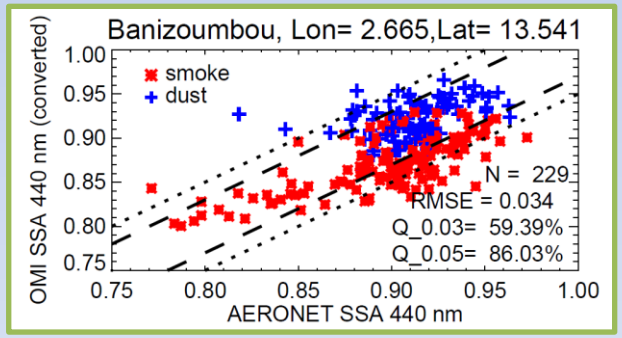
OMI Vs. AERONET
Seasonal Biomass Burning and Dust Sites

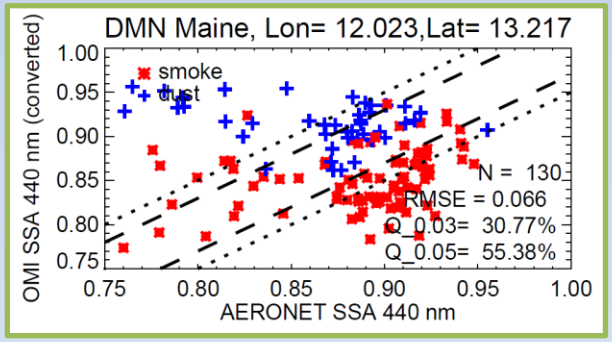






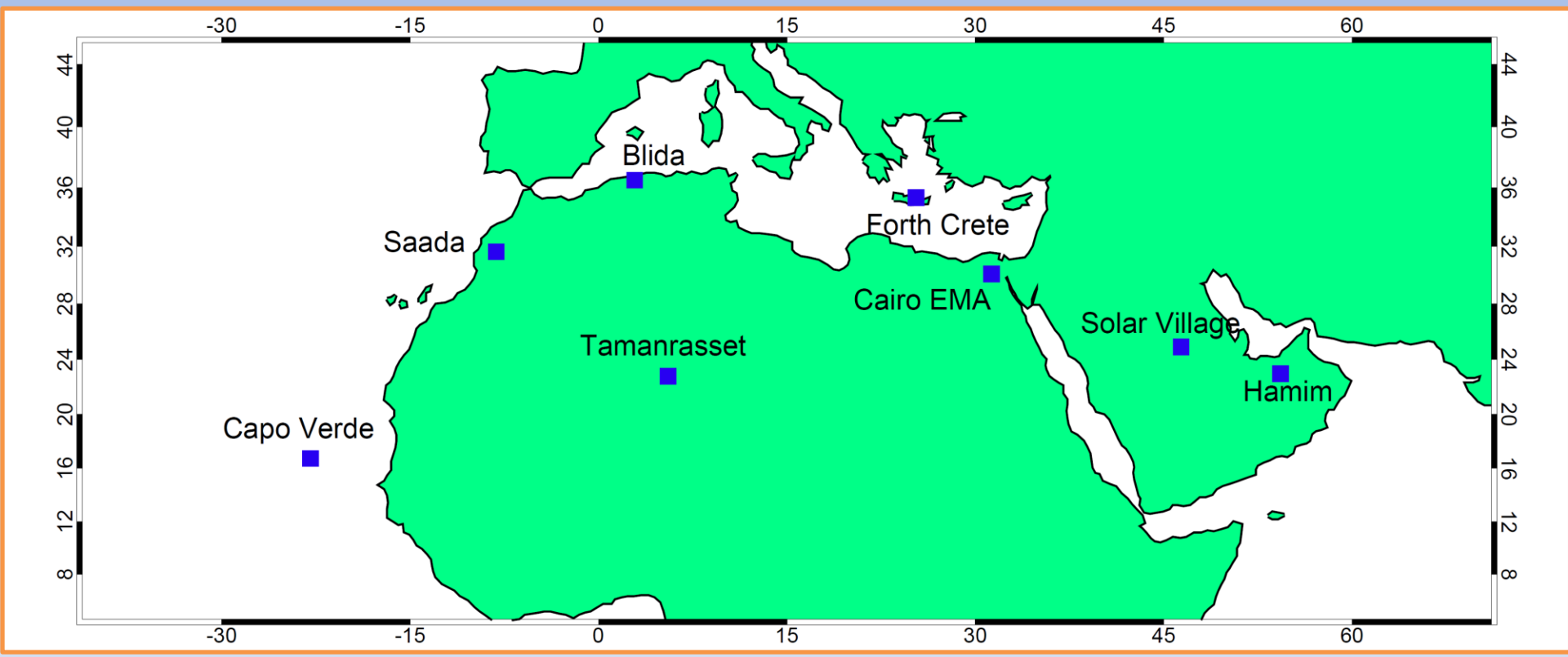




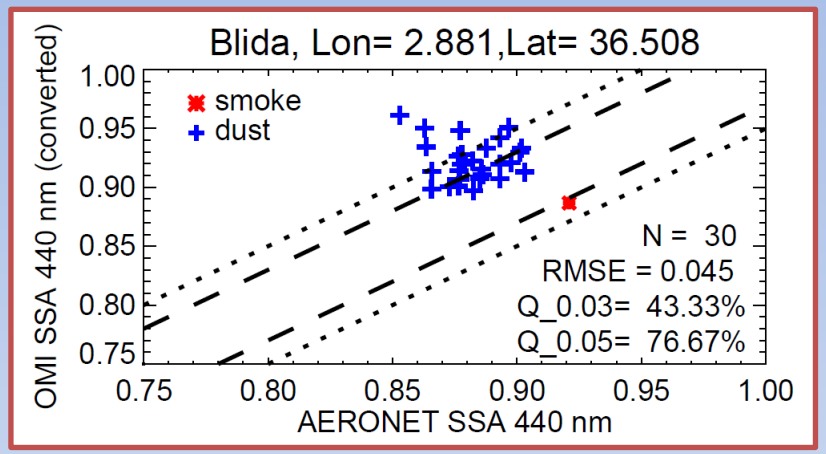


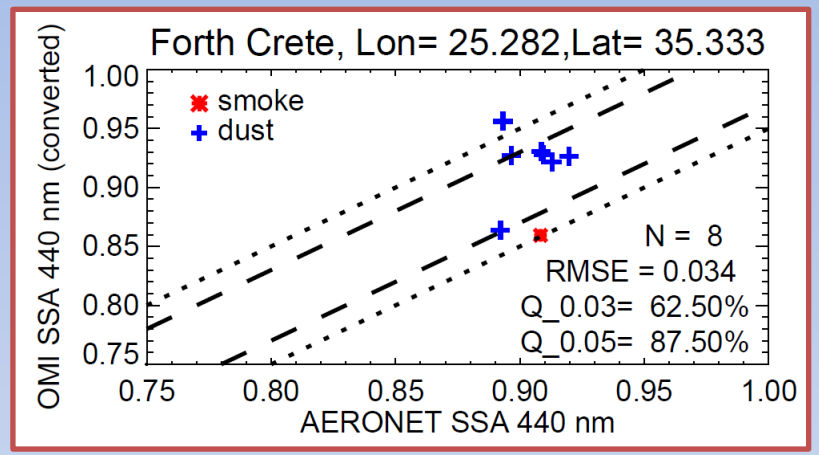
Performance of smoke models appears to be better than dust models

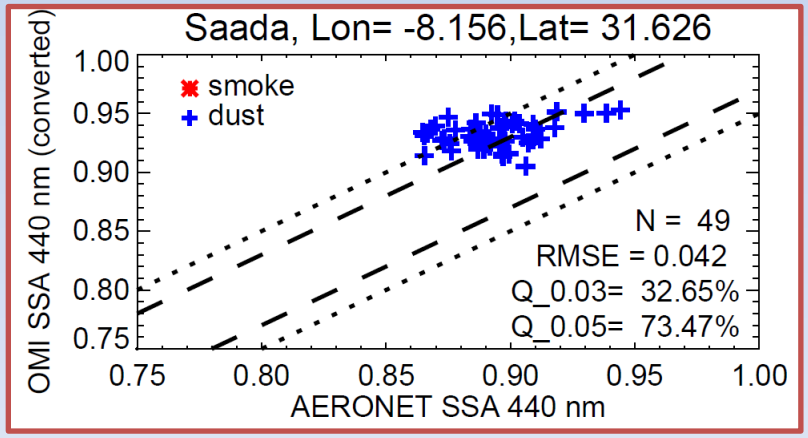
Dust Sites

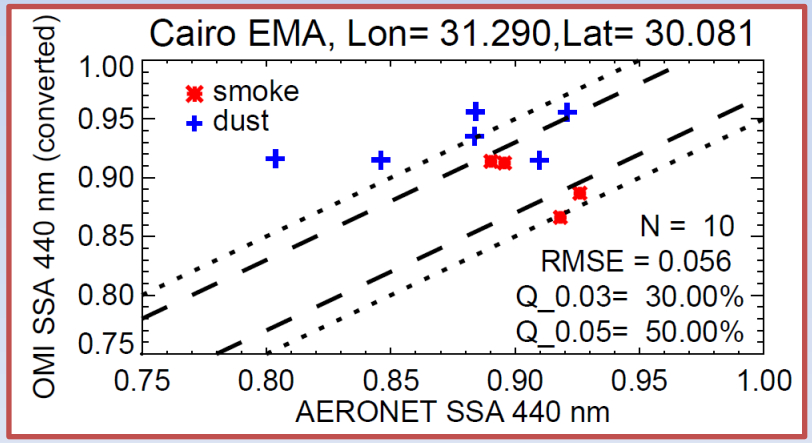

-30
-15
0
15
30
45
60
44
40
36
32
28
24
20
16
12
8
Blida
Saada
Forth Crete
Cairo EMA
Solar Village
Tamanrasset
Hamim
Capo Verde

OMI Vs. AERONET
Dust Sites

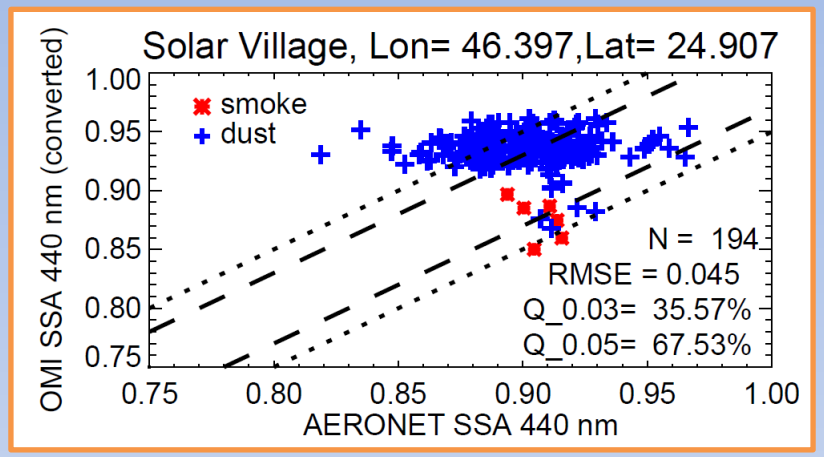


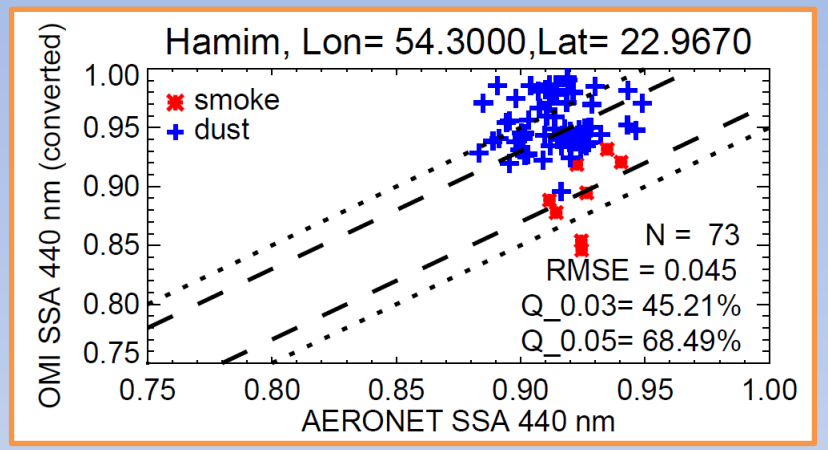


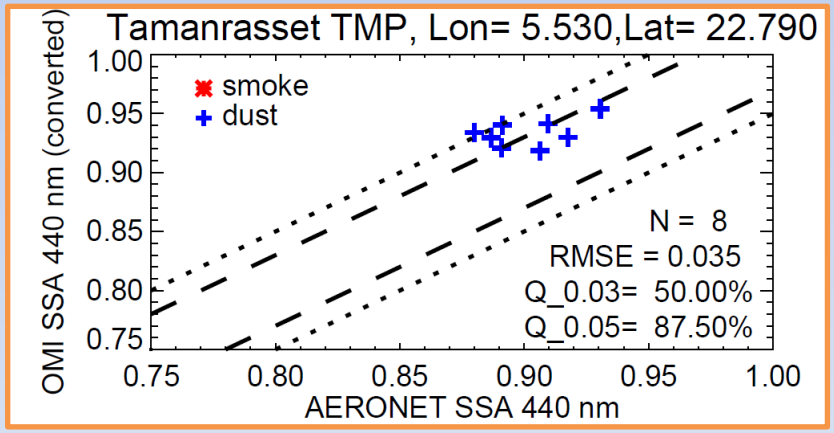


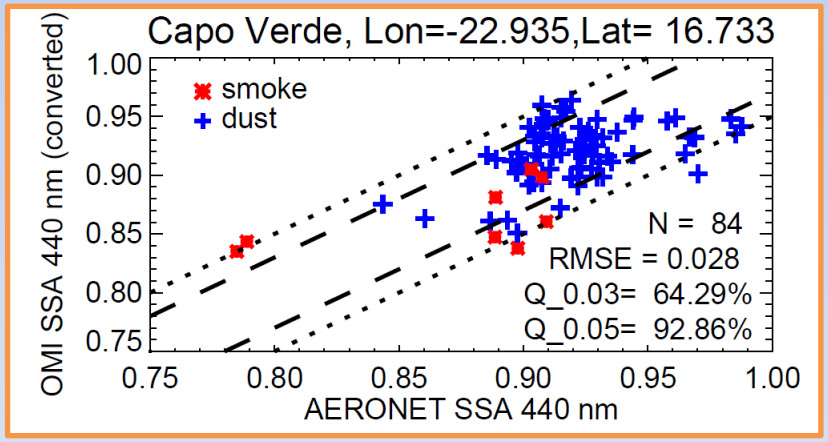


OMI Vs. AERONET
Dust Sites





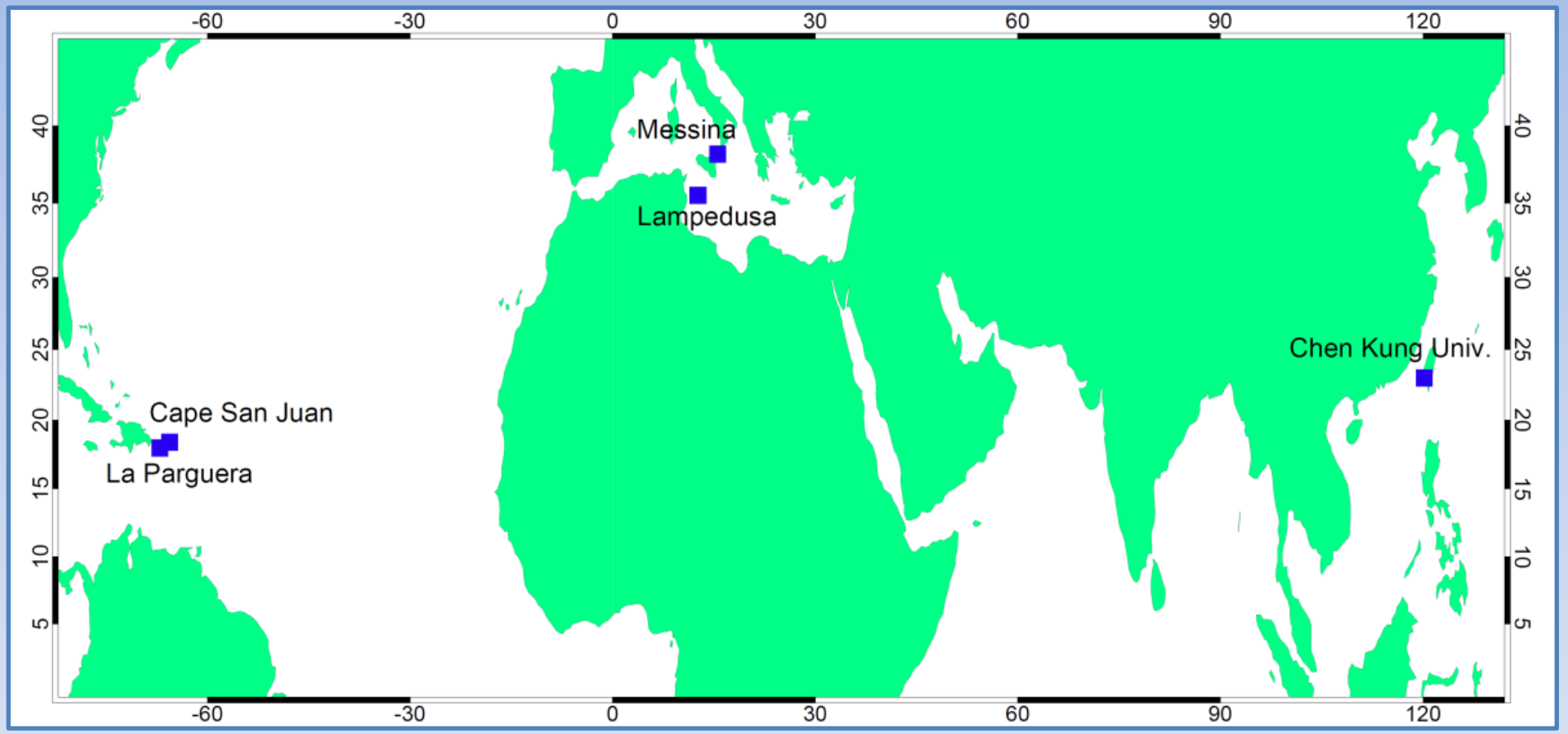




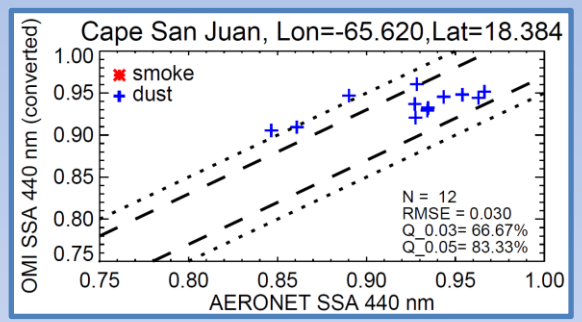
Over-estimation in SSA for more absorbing dust aerosols over LAND

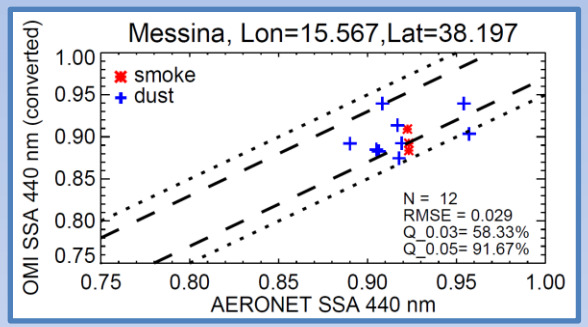
However, good agreement over an oceanic site for the same aerosol type!

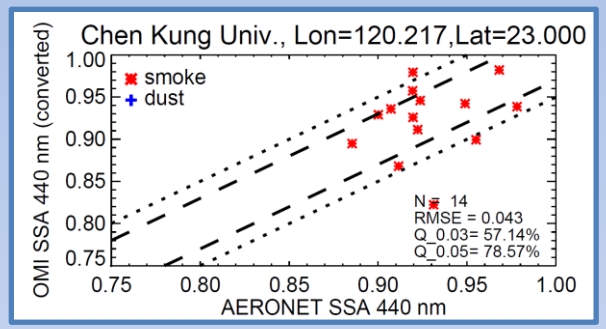
Oceanic Sites



Oceanic Sites
OMI Vs. AERONET

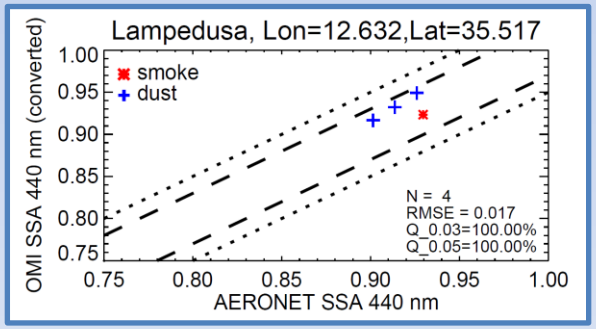


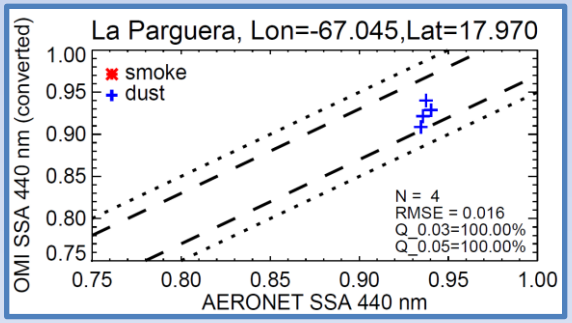




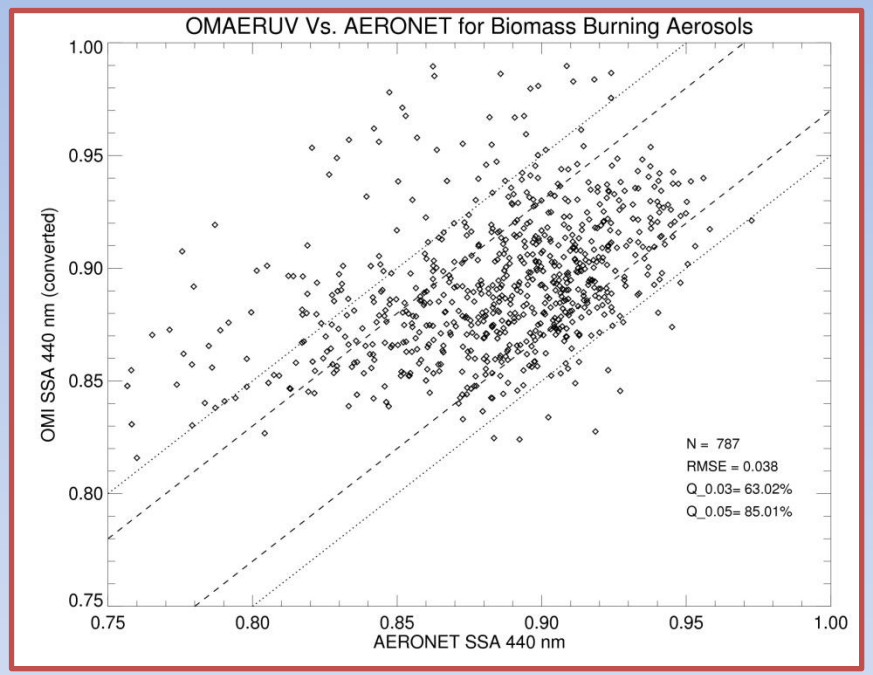
Poor sampling in co-location

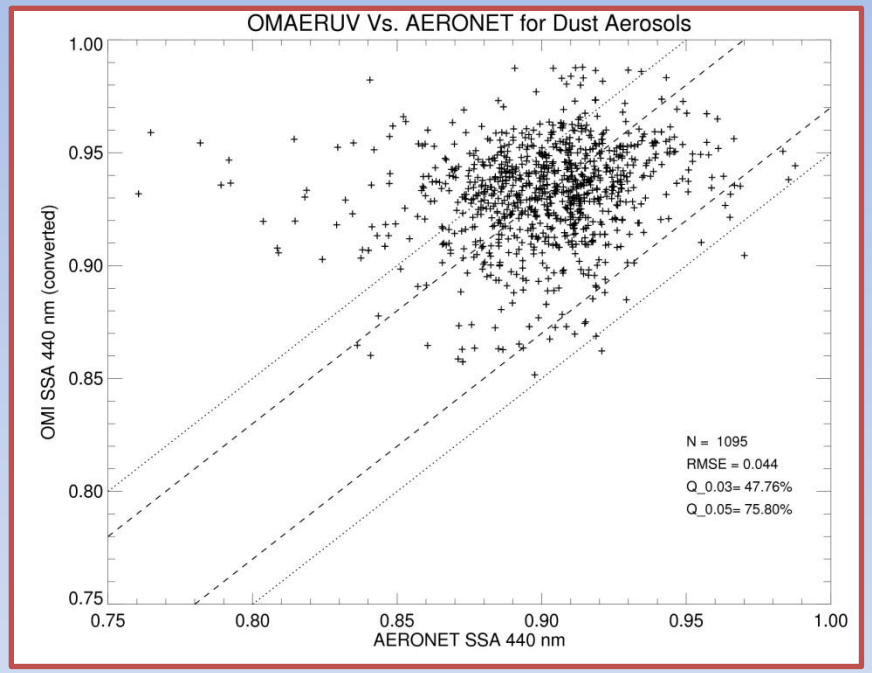
Overall better agreement





Summary Plots





Possible sources of Errors

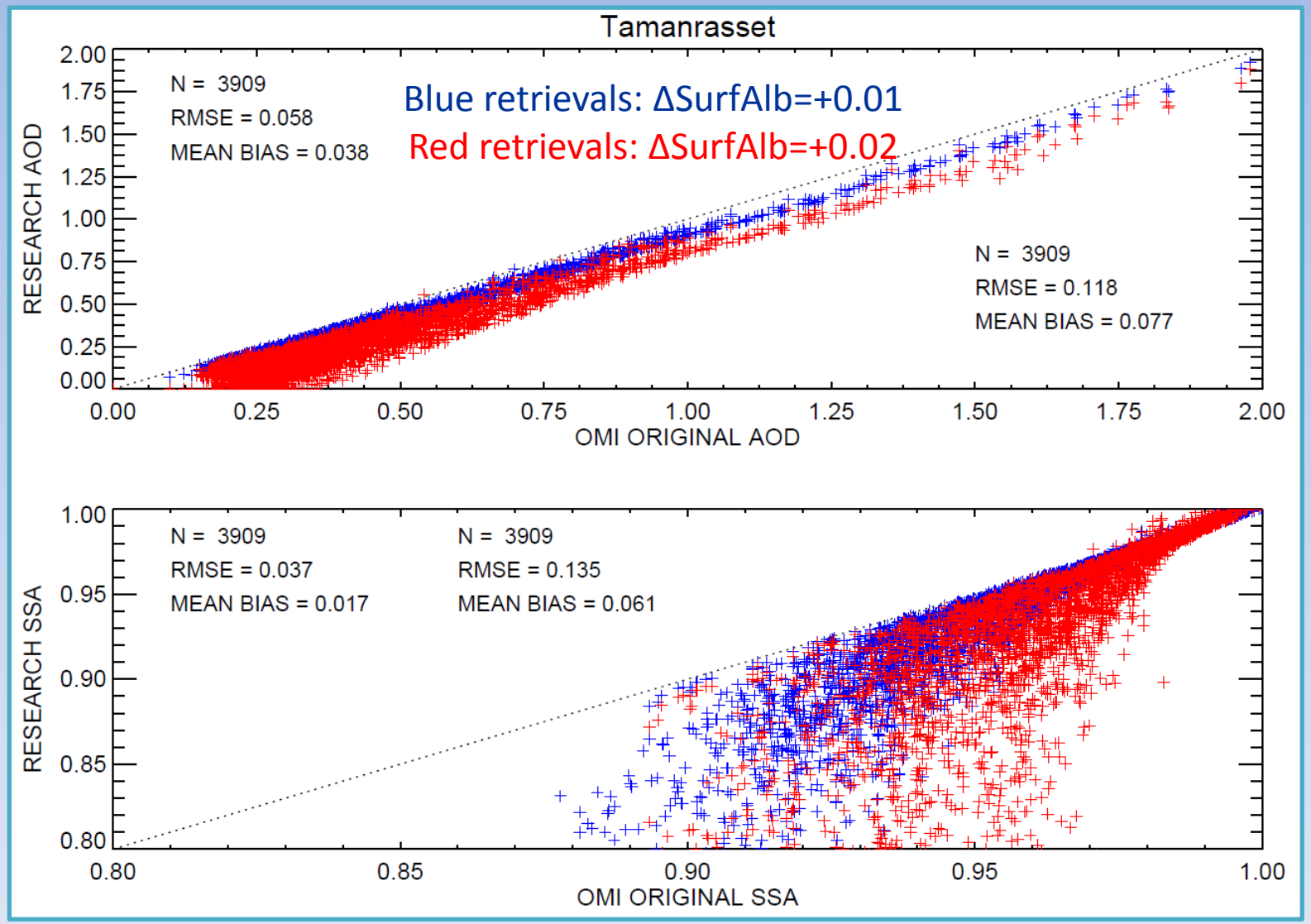
1. Sub-pixel cloud-contamination
   - not likely over desert sites
   - in fact retrievals are better over oceanic sites where chances of sub-pixel CC is likely

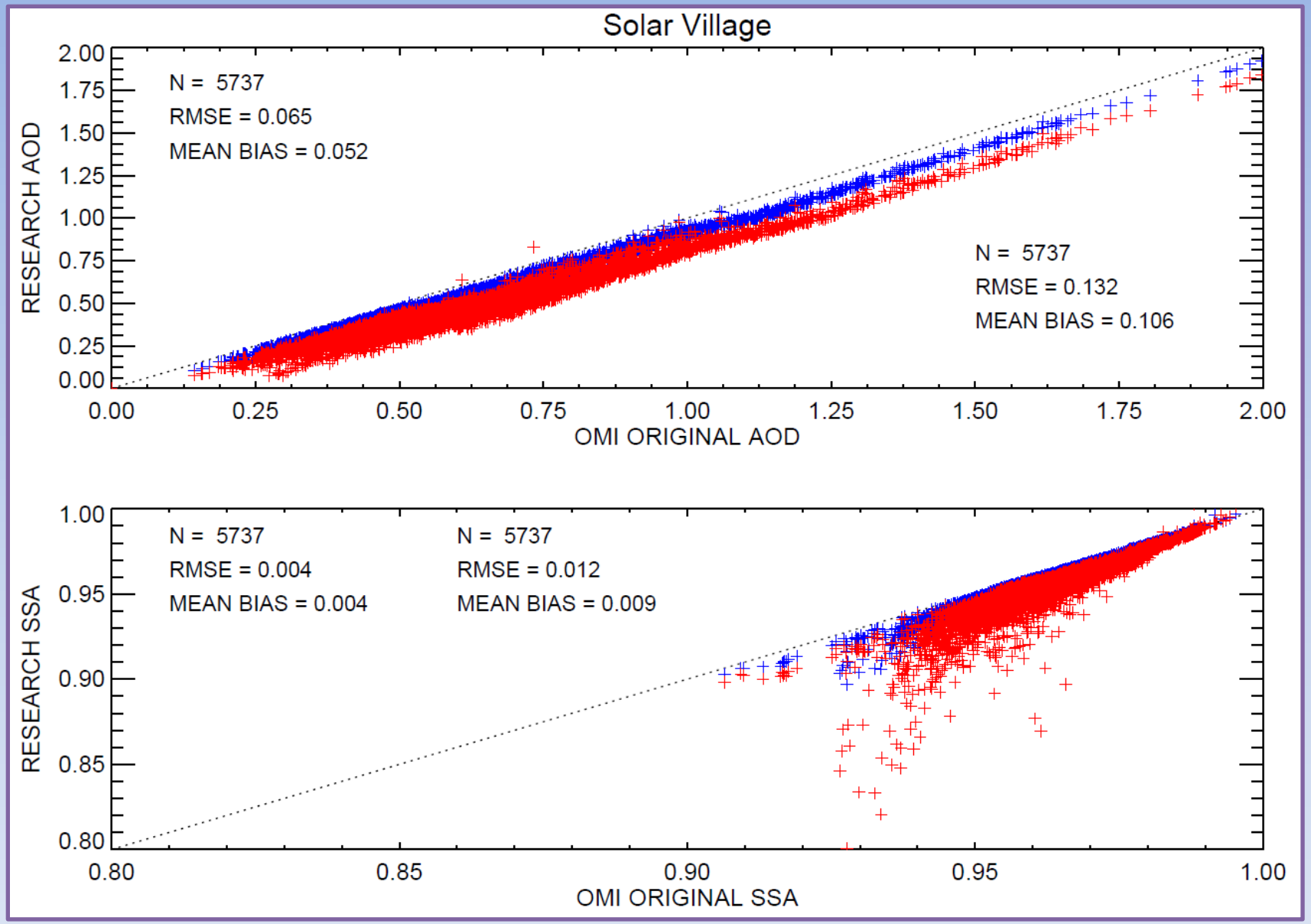
2. Aerosol layer height
   - this assumption is now well constrained by the observed vertical profile of aerosols from CALIOP

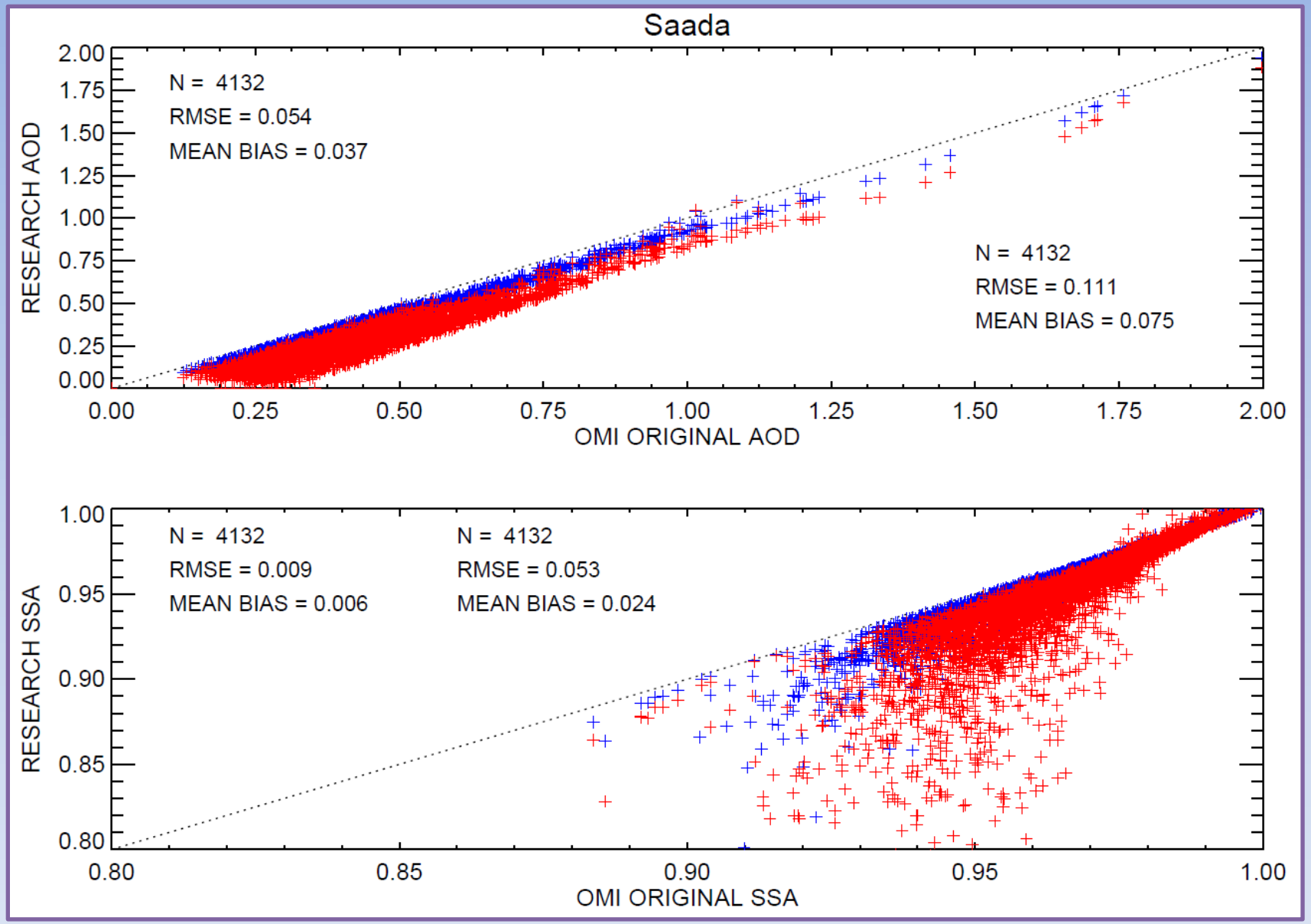
3. Surface albedo
   - land-ocean contrast in the quality of retrievals gives a hint on this issue

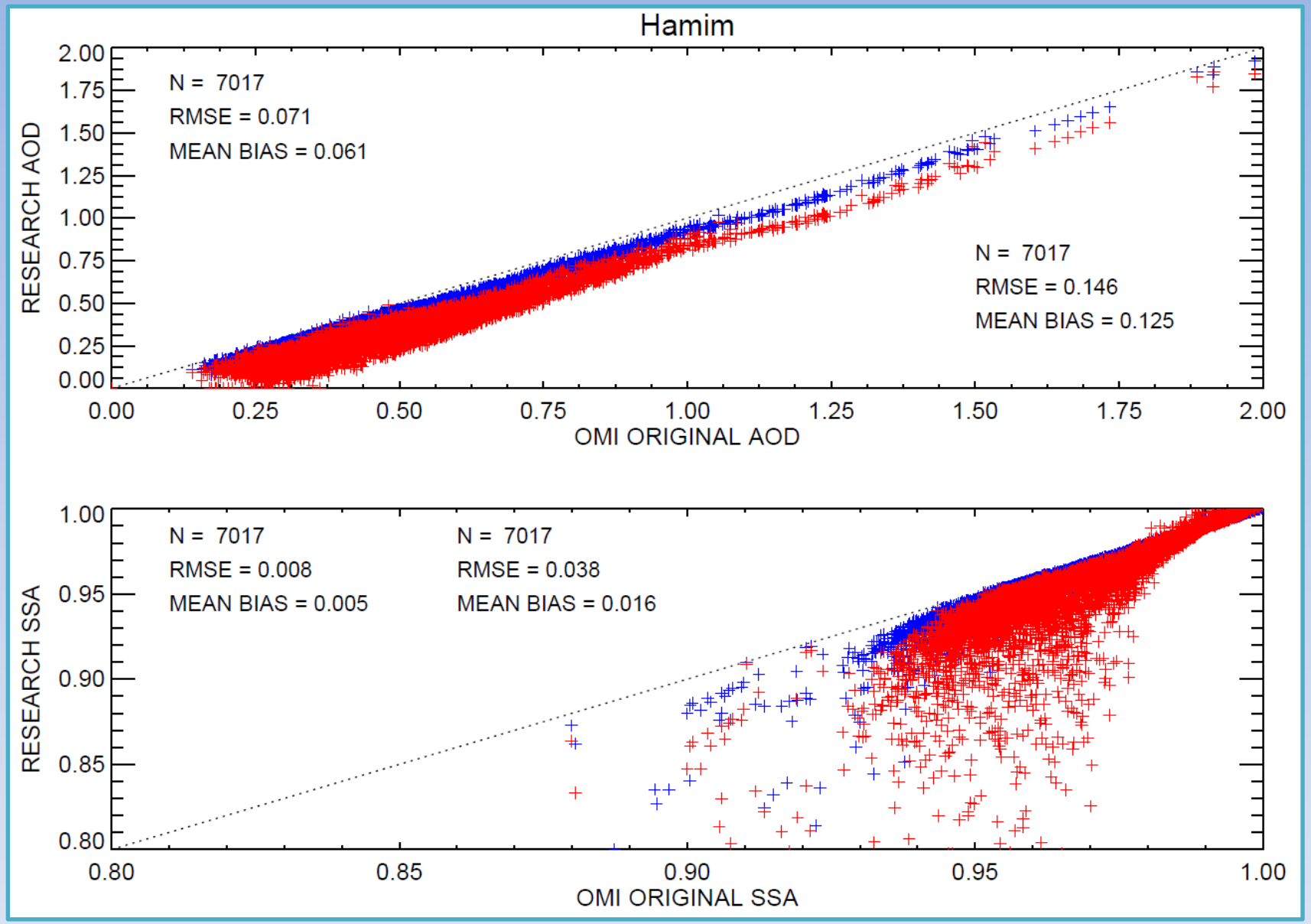
4. Non-spherical shape of the particles
   - the non-spherical shape of the dust particles could impact the retrieval through difference in phase function

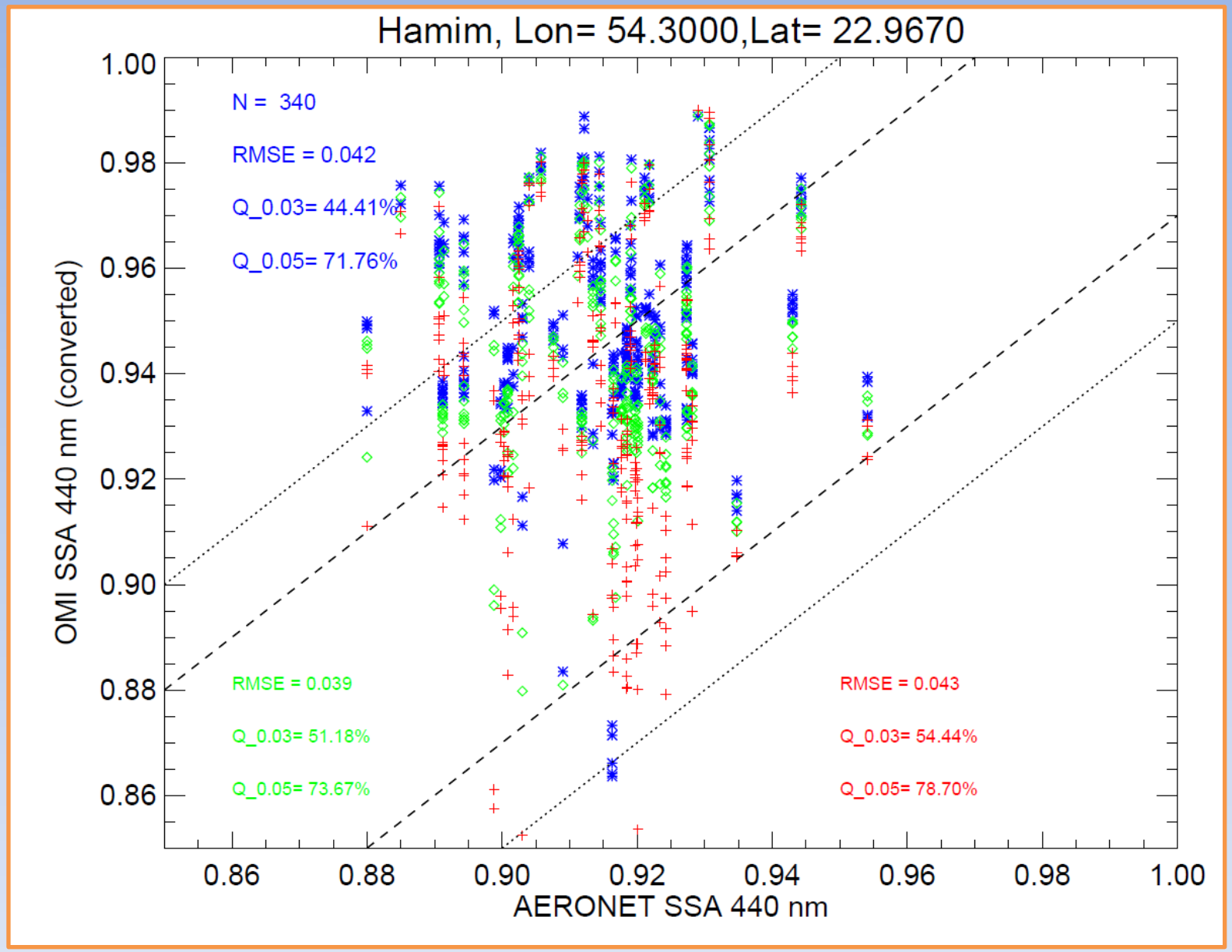
OMI Vs. AERONET
Sensitivity of Retrieval to Change in Surface Albedo

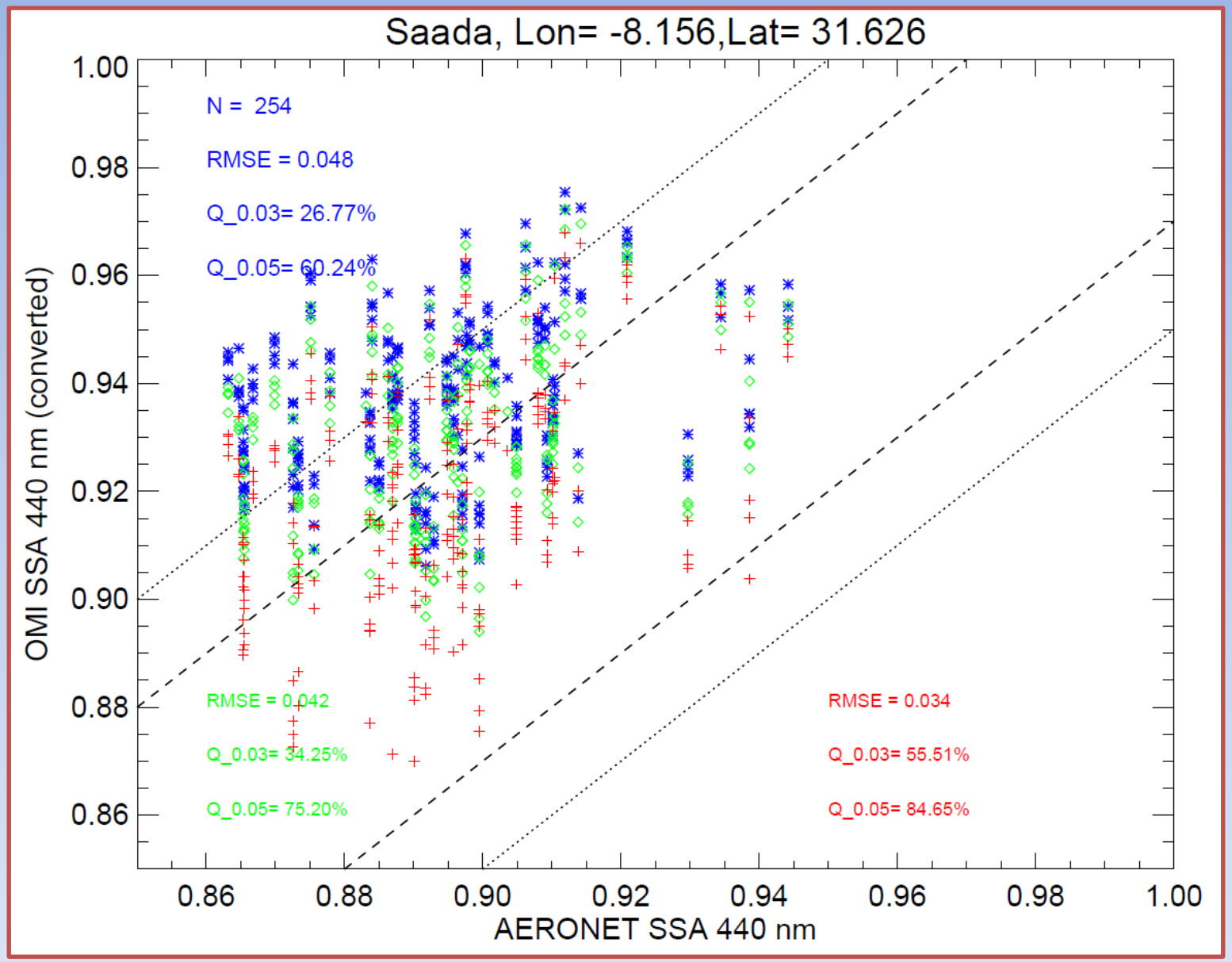



Solar Village
N = 5737
RMSE = 0.065
MEAN BIAS = 0.052
N = 5737
RMSE = 0.132
MEAN BIAS = 0.106
RESEARCH AOD
OMI ORIGINAL AOD
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
N = 5737
RMSE = 0.004
MEAN BIAS = 0.004
N = 5737
RMSE = 0.012
MEAN BIAS = 0.009
RESEARCH SSA
OMI ORIGINAL SSA
0.80
0.85
0.90
0.95
1.00


Saada
N = 4132
RMSE = 0.054
MEAN BIAS = 0.037
N = 4132
RMSE = 0.111
MEAN BIAS = 0.075
RESEARCH AOD
OMI ORIGINAL AOD
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
N = 4132
RMSE = 0.009
MEAN BIAS = 0.006
N = 4132
RMSE = 0.053
MEAN BIAS = 0.024
RESEARCH SSA
OMI ORIGINAL SSA
0.80
0.85
0.90
0.95
1.00


Hamim
N = 7017
RMSE = 0.071
MEAN BIAS = 0.061
N = 7017
RMSE = 0.146
MEAN BIAS = 0.125
RESEARCH AOD
OMI ORIGINAL AOD
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
N = 7017
RMSE = 0.008
MEAN BIAS = 0.005
N = 7017
RMSE = 0.038
MEAN BIAS = 0.016
RESEARCH SSA
OMI ORIGINAL SSA
0.80
0.85
0.90
0.95
1.00


Hamim, Lon= 54.3000,Lat= 22.9670
N = 340
RMSE = 0.042
Q_0.03= 44.41%
Q_0.05= 71.76%
RMSE = 0.039
Q_0.03= 51.18%
Q_0.05= 73.67%
RMSE = 0.043
Q_0.03= 54.44%
Q_0.05= 78.70%
OMI SSA 440 nm (converted)
AERONET SSA 440 nm
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.86
0.88
0.90
0.92
0.94
0.96
0.98
1.00


Saada, Lon= -8.156,Lat= 31.626
N = 254
RMSE = 0.048
Q_0.03= 26.77%
Q_0.05= 60.24%
RMSE = 0.042
Q_0.03= 34.25%
Q_0.05= 75.20%
RMSE = 0.034
Q_0.03= 55.51%
Q_0.05= 84.65%
OMI SSA 440 nm (converted)
AERONET SSA 440 nm
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.86
0.88
0.90
0.92
0.94
0.96
0.98
1.00

Summary

- We have come up with an updated OMI/OMAERUV aerosol algorithm and resulting re-processed retrieval.
  - ✓ inclusion of organics in carbonaceous models
  - ✓ observed aerosol layer heights from CALIOP
  - ✓ robust identification of aerosol type using AIRS CO and OMI UV-AI data

- The new retrievals have been compared with the **AERONET** direct measurements (AOT) and retrievals (SSA).

- The OMI retrievals of SSA found to be in good agreement over biomass burning sites; about 60-70% retrievals within ±0.03 uncertainty.

- The dust SSA retrievals are being over-estimated for more absorbing aerosols. The surface albedo assumption and impact of non-spherical shape of the dust particles need to be investigated.

Thanks for your kind attention!

Backup slides…

Smoke Models

Model	Img. Ref. Index			SSA		
	354 nm	388 nm	500 nm	354 nm	388 nm	500 nm
SSA0781	0.0567	0.0480	0.0480	0.7577	0.781	0.7513
SSA0808	0.0480	0.0400	0.0400	0.7876	0.808	0.7812
SSA0846	0.0360	0.0300	0.0300	0.8288	0.846	0.8225
SSA0888	0.0240	0.0200	0.0200	0.8753	0.888	0.8694
SSA0944	0.0120	0.0100	0.0100	0.9346	0.944	0.9380
SSA0877	0.0060	0.0050	0.0050	0.9646	0.970	0.9665
SSA1000	0.0000	0.0000	0.0000	1.0000	0.9999	1.0000

Imaginary part of refractive index is NOT same for three wavelengths, meaning spectral dependence in absorption (“gray” aerosols)

SSA is different due to difference in absorption at three wavelengths (increasing SSA from shorter to longer wavelengths)

Dust Models

Model	Img. Ref. Index			SSA		
	354 nm	388 nm	500 nm	354 nm	388 nm	500 nm
DST1	0.0230	0.0166	0.0073	0.7352	0.7655	0.8530
DST2	0.0128	0.0092	0.0040	0.7972	0.8292	0.9069
DST3	0.0083	0.0060	0.0026	0.8408	0.8708	0.9340
DST4	0.0056	0.0040	0.0018	0.8768	0.9029	0.9520
DST5	0.0026	0.0019	0.0008	0.9319	0.9486	0.9764
DST6	0.0013	0.0009	0.004	0.9622	0.9723	0.9878
DST7	0.0000	0.0000	0.0000	1.0000	0.9999	1.0000

Imaginary part of refractive index is NOT same for three wavelengths, meaning spectral dependence in absorption (“gray” aerosols)

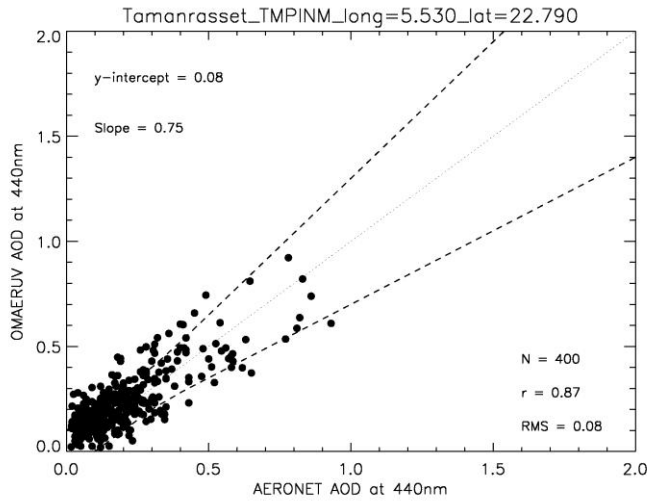
SSA is different due to difference in absorption at three wavelengths (increasing SSA from shorter to longer wavelengths)

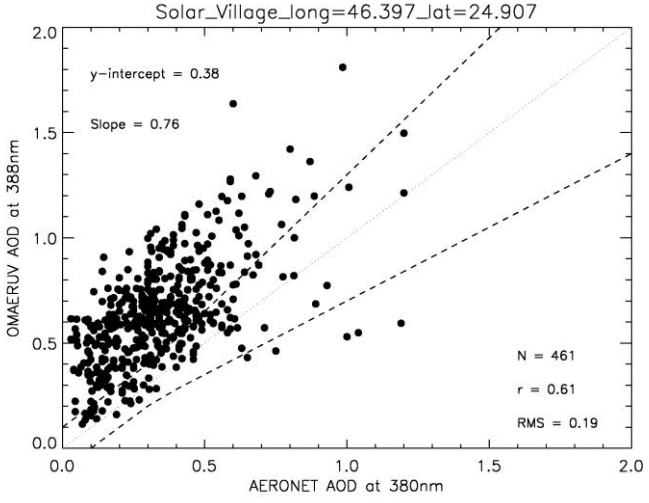
Industrial/Sulphate Models

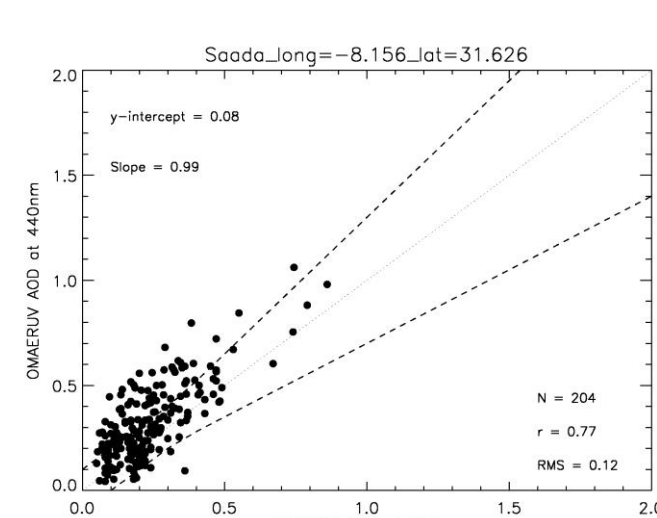
Model	Img. Ref. Index			SSA		
	354 nm	388 nm	500 nm	354 nm	388 nm	500 nm
IND1	0.0120	0.0120	0.0120	0.9172	0.9131	0.8970
IND2	0.0100	0.0100	0.0100	0.9290	0.9254	0.9117
IND3	0.0080	0.0080	0.0080	0.9431	0.9383	0.9270
IND4	0.0060	0.0060	0.0060	0.9543	0.9519	0.9432
IND5	0.0040	0.0040	0.0040	0.9681	0.9665	0.9605
IND6	0.0020	0.0020	0.0020	0.9831	0.9822	0.9791
IND7	0.0000	0.0000	0.0000	1.0000	0.9999	1.0000

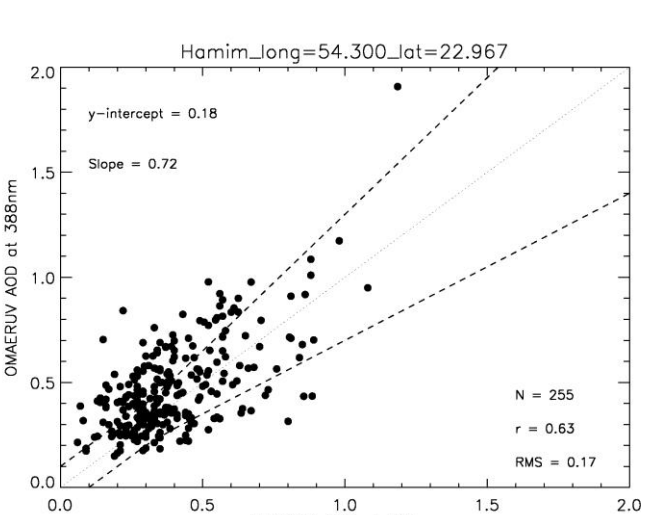
Imaginary part of refractive index is same for all three wavelengths, meaning no spectral dependence in absorption ("gray" aerosols)

SSA is different due to difference in wavelengths


Tamanrasset_TMPINM_long=5.530_lat=22.790
y-intercept = 0.08
Slope = 0.75
N = 400
r = 0.87
RMS = 0.08
OMAERUV AOD at 440nm
AERONET AOD at 440nm


Solar_Village_long=46.397_lat=24.907
y-intercept = 0.38
Slope = 0.76
N = 461
r = 0.61
RMS = 0.19
OMAERUV AOD at 388nm
AERONET AOD at 380nm


Saada_long=-8.156_lat=31.626
y-intercept = 0.08
Slope = 0.99
N = 204
r = 0.77
RMS = 0.12
OMAERUV AOD at 440nm
AERONET AOD at 440nm


Hamim_long=54.300_lat=22.967
y-intercept = 0.18
Slope = 0.72
N = 255
r = 0.63
RMS = 0.17
OMAERUV AOD at 388nm
AERONET AOD at 380nm